The case for maglev: Paying more is cheaper

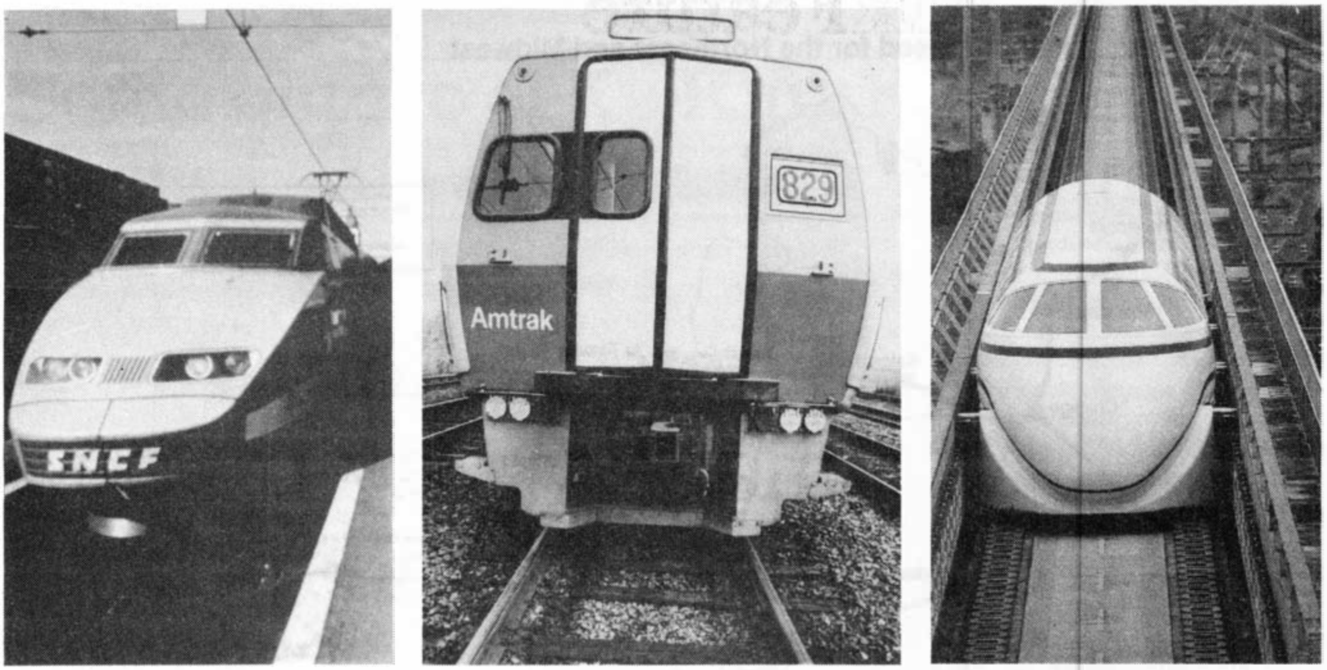
by Chris White

This article on infrastructure and economic development costs in transportation, is part of an ongoing series of economic studies of the physical economy. The first in the series, entitled "Infrastructure and Economic Development," appeared in the May 29 EIR.

The Bush administration has announced plans to spend $30 million over the next six years "to study" high-speed rail transportation in five so-called "corridors." The funding for the studies was provided under the five-year, $150 billion Transportation Act of 1991. The five corridors include lines from Chicago to Detroit, Milwaukee, and St. Louis; a stretch between Miami, Tampa, and Orlando; a line linking Washington, D.C. with Charlotte, North Carolina via Richmond, Virginia; various routes in California; and a link between Seattle and Vancouver, British Columbia. Ceremonies are being organized in different parts of the country to celebrate the announcements. It is not known how much of the first $7 million outlay will be spent for the celebrations.

The study plans are another absurdity, presumably to be inherited by whoever becomes President after Nov. 3. There is one viable option for upgrading U.S. surface transportation, the magnetic levitation system known as maglev. No more studies are needed to establish that. The system, in its first-generation form, will provide a starting point for providing this country, and any other, with a transportation system fit for the twenty-first century. It will upgrade inter-city transportation, and will provide a means for modernizing broken-down urban mass transit systems or developing them where they do not exist. Maglev will revitalize manufacturing industries and bombed-out industrial urban centers alike.

This article reviews the case for maglev as a transport system, by way of a review of flawed earlier studies on high-speed rail options for the United States. This is to establish economic cost parameters in this area of infrastructure development, and to debunk the prevailing, usurious financial criteria which are used to



Left to right: the French high-speed TGV; Amtrak's Metroliner; and a Japanese magnetically levitated MLU 001, a test model running on a u-shaped track which must be specially built for it. Which approach is really *the most economical?*

determine the viability, or non-viability, of such projects.

The study projects announced by Transportation Secretary Andrew Card during October are nothing new. With the exception of the link between Seattle and Vancouver, all of the identified projects have been studied repeatedly since 1980. Nothing has been done on any of them. I have before me a selection of such study reports and project prospectuses. They include the Office of Technology Assessment's 1983 study entitled "U.S. Passenger Rail Technologies"; the 1984 assessment entitled "High Speed Rail in the Midwest," prepared by the Federal Reserve Bank of Chicago; the prospectus prepared by the Advanced Rail Consortium, entitled "High-Speed Rail Service in the Detroit-Chicago Corridor," issued in 1985; "Jobs With a Future," a 1984 report to document the employment-creating benefits of a high-speed rail program in Ohio for the Ohio Rail Transportation Authority; the Florida High Speed Rail Committee's 1984 report "Florida's Future Advanced Transportation"; and the June 1985 final report of the Ohio High Speed Rail Task Force.

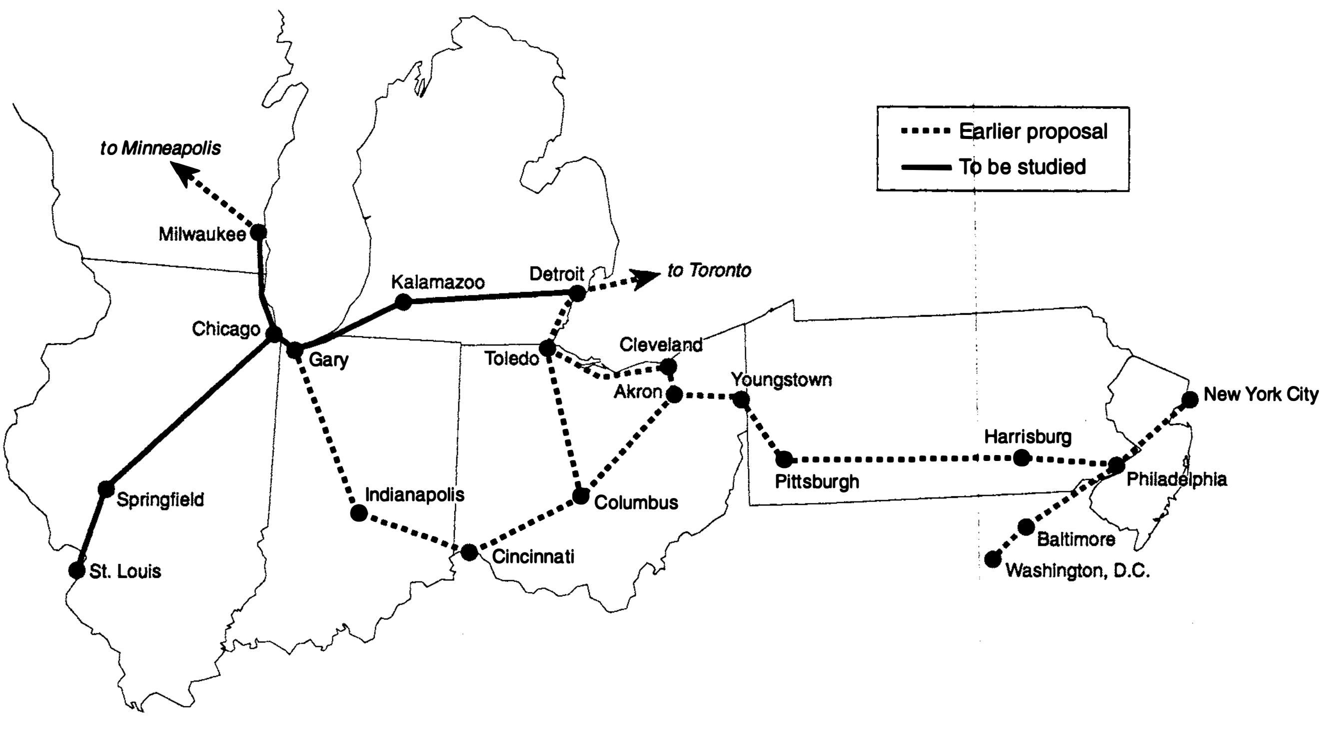
These by no means exhaust the list of projects which were prepared beginning in 1978. What motivated the reports, primarily, was not the question of transportation, but rather how to create useful jobs to provide productive work for the millions of industrial workers who found themselves out on the streets because of the economic lunacy of Jimmy Carter and Paul Volcker. **Figure 1** shows some, but not all, of the routes which were under consideration in the Northeast and Midwest during the early 1980s. The three solid lines represent those which Card now proposes to study anew.

Employment creation was then as useful an objective as it is an urgent one today. And it remains true that the relationship posed between employment infrastructure projects, and employment in ancillary industries, in the Ohio study still holds. The authors estimated that construction of a line between Detroit and Toledo would create 34,000 jobs directly, and another 34,000 in ancillary industries once construction work was under way. But all those studies were flawed by economic idiocies associated with the ruling conception of cost. The Federal Reserve Bank's Midwest study is exemplary of the problem. It is not merely a problem limited to so-called experts. The blunders they make are the same as those which anybody who has had any kind of high school-level mis-education would also make.

Finance dominates over economics

The idiocies come up in the relationship, or lack thereof, between cost as an economic function, and financial considerations concerning how such projects should be paid for. To the extent there is ignorance of the economics of production, and there is a lot of it, such studies as the Chicago Federal Reserve's typifies end up being politely worded manuals for bankers on how to loot physical investment in capital improvements, through transforming the anticipated earnings of a project into a maximized cash stream flowing into the accounts of the bond-holders who "financed" the project. In this, bond-holders' concerns over the maintenance of a

FIGURE 1
High-speed rail lines proposed for the Northeast and Midwest



Source: U.S. Congress, Office of Technology Assessment, "U.S. Passenger Rail Technologies," 1983.

cash stream dominate in the definition of project viability, not economics per se.

This will undoubtedly be a major feature of whatever follows from the announcement of the renewed project studies. However, it is not only a matter for the United States. The method employed by the Chicago Federal Reserve to determine the viability of infrastructure development projects is the same employed the world over, through such agencies as the World Bank and related international organizations. To show how this approach leads to economic absurdity is therefore to help debunk the approach which is impelling the entire world into depression and genocide in the name of "cost efficiency." It also helps in the necessary work of developing rational alternatives to such criteria for developing investment priorities in the urgent global work of infrastructural development.

It as well to be clear about what is involved.

The Chicago Federal Reserve took three categories of high-speed rail transportation: High Speed, Very High Speed, and Super High Speed. In the first category were systems such as Amtrak's 87-mile-per-hour (mph) Metroliner service in the Northeast corridor, and Britain's 125-mph High Speed Train (HST) which entered service in 1972. In the second category were France's TGV and the Japanese Shinkansen, which are steel-wheel on steel-rail technologies, which were then operating at speeds in excess of 160 mph. And in the third, Germany's wheel-less, linear-induction motor-powered maglev system, capable of operating speeds of 300 mph, under entirely new physical principles—no moving parts, using electro-magnetic effects.

The report's conclusions were that "the capital costs for a Very High Speed system are double those for a High Speed system, and the capital costs for a Super High Speed system are double those for a Very High Speed system. Thus, it appears that the cost of increasing rail operating speed increases at an increasing rate . . . [and] the frequency of service for which the system is designed has a significant impact on costs. . . . Improving rail service by adding more trains per day is costly, regardless of the technology. Improving service by introducing technologies that reduce travel time significantly is a much more expensive undertaking."

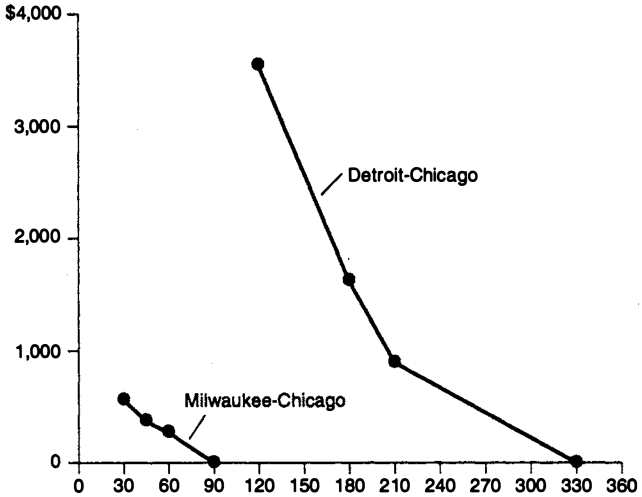
In this vein, the Advanced Rail Consortium, which included the Bechtel Corp., Morgan Grenfell, and Transmode, Inc. (then the U.S. subsidiary of British Rail), recommended the British HST for the Detroit-Chicago corridor on the grounds of so-called cost-effectiveness, given the proven revenue generating record of an in-service capability. Whether that view would be changed now, nine years later, must be open to doubt.

The Fed's assessment was uniquely based on the per mile

FIGURE 2

The trade-off between capital expenditures and travel time

(capital cost for 12 trains/day in millions $)

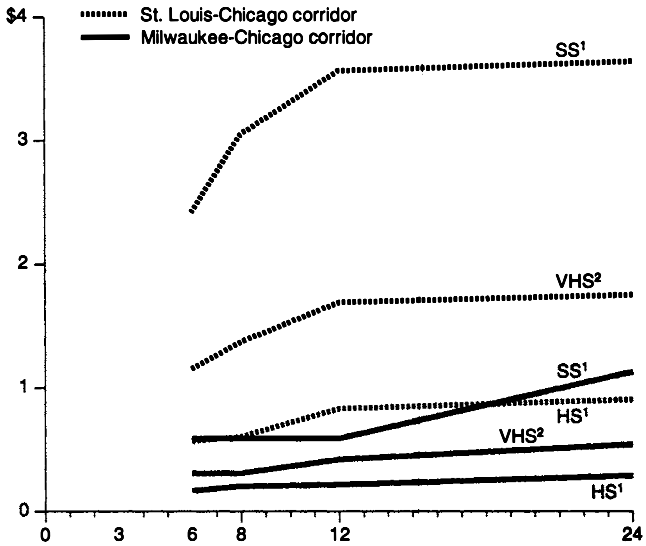


Source: Federal Reserve Bank of Chicago, "High-Speed Rail in the Midwest: An Economic Analysis," Chicago, 1984.

FIGURE 3

The effect of frequency on the capital costs of three high-speed rail systems

(capital costs, billions $)



1. Super speed (maglev).
2. Very high speed (TGV and Shinkansen).
3. High speed (Metroliner and British Rail).

Source: Federal Reserve Bank of Chicago, "High-speed Rail in the Midwest: An Economic Analysis," Chicago 1984.

or per kilometer cost of building track. In their approach, the Metroliner and British HST versions are ostensibly the cheapest, because they can run on upgraded, existing tracks. TGV and Shinkansen require new track, probably on new right of way, and therefore cost more. The elevated guideway design of Germany's maglev increases costs further, it appears. The basic unit considered was a single-track layout. Frequency of service, counted in number of trains per day and vehicle-miles per year, not even number of passengers carried per day or year, was added to the list of assumed parameters to estimate the conditions under which a double-tracked layout would be required. Hence, increasing service frequency can be said to double cost, because track and guideways double, at a certain point.

On a single track layout, the number of times trains running in opposite directions cross increases as the square of the number of trains. Two trains in each direction will cross four times, and so on. Frequency of service in both directions defines a number of crossings, and therefore a required number of crossing loops to partially double the single track. At a certain point, as frequency increases, it is better to build a second track, rather than more crossing loops.

Figures 2 and **3,** "Trade-off between Capital Expenditures and Travel Times" and "Effect of Frequency on Capital Costs," summarize the Fed's conclusions. The first purports to show how reducing travel times in the Detroit-Chicago and Milwaukee-Chicago corridors increases capital costs, at an increasing rate. The second shows how increasing the frequency of service accomplishes the same effect.

In Figure 2, the end point of each line touching the horizontal axis is the presently scheduled running time, in minutes, between each of the three cities. The three points on each line identify the effects of the three technologies studied in reducing travel time, and scale to the vertical axis which represents cost. Figure 3 shows how increasing frequency of service in the two corridors increases costs, up to a certain point. That point is where the whole corridor is double-tracked. Once the whole corridor is double-tracked, the cost escalation levels off, except for the maglev systems.

Determining system costs

The fallacy in the Fed's study is the assumption that per mile or per kilometer, or kilometer-track costs are an adequate basis for determining costs. They are not. Rail tracks, like roads, are designed to carry a volume of traffic, vehicles per hour, and the vehicles, in turn, are designed to carry either passengers or freight. Costs ought to be defined in terms of the relative capacities of the system. For example, since doubling tracks more than doubles the capacity of one track, because trains can run in both directions on the doubled track simultaneously, double tracking might well lower costs, because of its capacity-increasing effects.

The per mile or per kilometer cost of constructing track or guideway is only a starting point for assessing costs. What the Chicago study overlooked is the purpose for which the tracks and guideways are to be built. That is, to carry a certain

TABLE 1
Parameters for passenger transportation

Mode	Key*	Investment cost (millions $/km) min.	max.	Speed (km/h)	Right of way lane width (meters)	Passengers per transit unit min.	max.	Frequency (transit units per hour)	Line capacity (passengers per hour)
Automobiles on streets	Auto	$0.1	$ 1	50	3.5	1.2	2	800	1,600
Automobiles on freeways	Fway	1	7.5	90	3.65	1.2	2	2,000	4,000
Regular buses	Bus	0.05	0.2	25	3.5	40	120	120	14,400
Streetcars	Scar	0.5	1	20	7.5	100	540	120	64,800
Light rail transit	LRT	1.75	6	45	8	110	1,000	90	90,000
Rapid rail transit	RRT	4	12.5	60	8	140	2,800	40	112,000
Regional rail	RR	5	12.5	70	8	140	2,100	30	63,000
Metroliner type	HSR	0.92	2.8	131.2	8		350	5	1,750
Train à grande vitesse	TGV	1.8	5	213	8		350	5	1,750
Shinkansen	SK	1.8	5	213	8		1,340	10	13,400
German EMS maglev	TR07	3.4	10	500	18.2		200	10	2,000
Japanese EDS maglev	Chuo	3.4	10	500	18.2		980	12	11,760
Boeing 737	B-737			442			128	6	768

* Abbreviation used in many of the charts in this article.

Sources: U.S. Department of Transportation, Federal Railroad Administration, "Assessment of the Potential for Magnetic Levitation Transportation Systems in the *Public Transportation, Systems and Technology,* Prentice-Hall, 1981.

volume of traffic. The inclusion of "frequency of service" as a cost parameter, in the way indicated, is a further obfuscation of the matter.

What is volume of traffic? First, the traffic carried over the tracks or guideways is not simply the number of vehicles, but the number of passengers or tons of freight the vehicles can carry. A vehicle can carry a certain number of passengers, and a train, a transport unit, is made up of a number of such vehicles. Frequency of service is not some arbitrary number. It is determined by the headway between transport units required for safety. Headway times are determined, for example, by the time, and thus the track length required at a given operating speed, to brake to a halt, without running into the unit in front or causing a chain reaction pile-up behind. It is a concept familiar from safe highway driving practice. In rail systems, such matters are determined by the system used to control traffic, whether it is on board or centrally located, manual or automatic, as well as by the operating characteristics of the vehicles themselves.

The number of passengers carried per transport unit multiplied by unit frequency per hour, gives a number of passengers carried per hour. This is called the line capacity of the mode of transportation. The passengers are carried at a certain speed. The line capacity of the system multiplied by the operating speed gives the productive capacity of the system—the number of passenger-miles or passenger-kilometers produced per hour. Freight movements can be looked at in the same way.

Costs ought to be calculated on the basis of evaluations of a system's productive capacity and line capacity, not simply on the basis of the investment cost of each mile or kilometer of track. The reverse procedure leads to absurdities, such that the system which would appear to be the cheapest, in terms of cost per track mile or kilometer, may well turn out to be the most costly, when economic considerations, such as line capacity and productive capacity, are introduced. What the Chicago Federal Reserve did in the cited study is comparable to a shopper who buys meat, or potatoes, without reference to what is actually being bought for the money spent.

If that kind of thinking had prevailed earlier, we would never have gotten much beyond walking. After all, the costs of a horse, first to purchase or raise and then to maintain, are much greater than walking—maybe even more than double, since horses eat far more than people do. And, since horse-drawn omnibuses require more than one horse, as well as the conveyance which has to be built, they are plainly much more costly than horses for riding, maybe much more than double the cost, because omnibuses need more than two horses. As

Productive capacity (thousands passenger-km/h²)	Investment per passenger capacity per hour min. ($)	max. ($)	Investment per passenger-km capacity per hour (thousands $)
80	$ 62.50	$ 625.00	$1.25
360	250.00	1,875.00	2.78
360	3.47	13.89	0.14
1,296	7.72	15.43	0.39
4,050	19.44	66.67	0.43
6,720	35.71	111.61	0.60
4,410	79.37	198.41	1.13
229.6	525.71	1,600.00	4.01
372.75	1,028.57	2,857.14	4.83
2,854.2	134.33	373.13	0.63
1,000	1,700.00	5,000.00	3.40
5,880	289.12	850.34	0.58
339.456	0	0	0

U.S.," June 1990; *Jane's Book of World Railways,* 1985; Vukan Vuchic, *Urban*

for horse-drawn street cars, with all that capital investment in rail tracks, that's just ridiculous. This line of argument could quite easily have been put forward by the nineteenth-century predecessors of the Chicago Federal Reserve.

Yet, we did those things in the nineteenth century, and much more. And they worked. They worked because they cheapened the cost of transporting people. This seems to be a paradox which is not too well understood. If something appears to cost more, how can it be cheaper than something which, it appears, costs less?

In the electric utility industry, guidelines for achieving this type of result used to be known as the "six-tenths rule," after the ratio between the increase of the surface and the subtended volume of a sphere. In thinking about the continued growth of a given capacity of production, the assumption was that costs and capacity should grow by 0.6% and 1% to maintain the relationship found between the growth of the surface of a sphere, and the growth of the subtended volume. Growth could be maintained without producing a hot-air balloon where costs increase faster than capacity, or a rupturing explosion as growth of subtended volume exceeds the bounding surface.

This would begin to give us an economic cost function. The Chicago Federal Reserve was not concerned about economic cost functions. Nor were any of the other studies, up to and including the Department of Transportation's June 1990 assessment entitled "Moving America, New Directions, New Opportunities. An Assessment of the Potential for Magnetic Levitation Transportation Systems in the U.S."

Table 1 compares certain of the identified parameters for several modes of passenger transport. Four different types of ground transportation are included, and some comparable parameters derived from the Boeing 737 passenger plane.

The four types of ground transportation include: internal combustion engine-powered highway transportation, the passenger car on streets, the passenger car on freeways, and buses; various mass transit systems; street cars, which operate over the same or adjacent right of way as automobile traffic, light rail transit, fully grade-separated rapid rail transit, grade-separated and often completely underground regional rail systems, primarily for commuter traffic, such as the Paris RER; and the systems considered in the Chicago Fed report, with the addition of the design parameters for Japan's Chuo Linear Express, the equivalent of Germany's maglev.

The second column of Table 1 shows the abbreviations that will be used to indicate the various transportation modes in many of the figures that follow.

The parameters compared include investment costs per kilometer of highway, track, or guideway; operating speed in kilometers per hour (kmh); lane width or right of way; passengers per transit unit, (passengers per vehicle times vehicles per transit unit); frequency of service, in transit units per hour; line capacity, in passengers per hour; and productive capacity, in passenger-kilometers per hour. Where possible, estimated maxima and minima have been included. Capacity calculations were based on the estimated maxima.

Auto and mass transit modes are included for different reasons. The auto is included, because in the United States it dominates in a ridiculously uneconomical way. The mass transit systems are included because they help to emphasize the economic absurdity of the Chicago Fed's adopted cost-estimating method. These systems are primarily based on a review of European commuter networks, though the performance characteristics of the New York subway are comparable with other Rapid Rail systems (even if much more run down), and U.S. Light Rail and Street Car systems, where they exist, like in Boston, Massachusetts and Portland, Oregon, are also comparable.

In the high- and higher-speed rail modes, High Speed Rail presents the performance characteristics of Amtrak's Metroliner service in the Northeast corridor, the 87 mph rocket, which is actually slower than some of the express trains that used to be in service in the days of steam. The profiles of the French TGV and Japanese Shinkansen are based on national railway system reports in *Jane's World Railways*. A frequency of five per hour is assumed for the TGV, though the Paris-Lyons stretch is only covered by about one train per hour. Contrary to the Chicago Fed which assumes an arbitrary frequency range of 6 to 24 trains per day, the Shinkansen service between Tokyo and Osaka, in both Hikari Super Express and Kodoma Limited Express forms, runs every six minutes, with seats for more than 1,300 passengers on each train.

The profiles of the German and Japanese maglev systems are based on studies done by the Budd Corp., once the U.S. subsidiary of Transrapid, and the Department of Transportation. Table 1 presents data for the TR07, assuming two vehicles of 100-passenger capacity per unit. Different capacity unit layouts were proposed for U.S. service. Budd had wanted to employ a 500-passenger consist (i.e., an assembled train) between Los Angeles and Las Vegas, and an 800-passenger consist between Chicago and Milwaukee. Both the German and the Japanese systems are designed to operate with headways of 60 seconds, i.e., at a frequency of 60 units per hour. Frequencies of 10-12 per hour were chosen here.

Maglev will drop travel costs

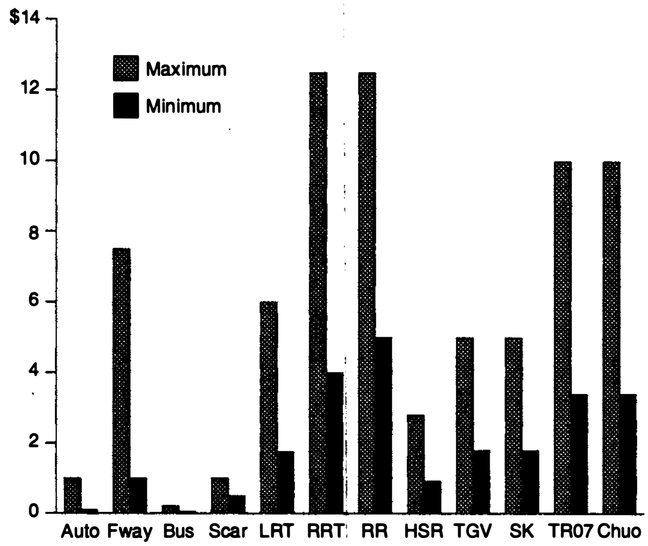
Adjusted to reflect the capacities recommended for U.S. service in the Budd studies, the parameters reported here help demonstrate the cost benefits which will accrue from the development of the potential of maglev systems, even in their first generation applications. Maglev can be expected to reduce the cost of inter-city travel down the scale to the level which in relatively sane economies has been associated with urban mass transit. That does not mean that inter-city trips would be priced out in units of cents instead of tens or hundreds of dollars. It does mean that the dollar cost of one-way travel between Boston and Washington, D.C., and New York City and Washington, ought to come down to around $50 and $30, respectively.

Increasing the speed at which passengers are carried, contrary to the assumptions of the Chicago Fed, increases the productive capacity of the system, just as increasing the number of passengers carried increases the line capacity. Increasing speed of service, therefore, also should decrease cost, just as a system which can carry more passengers than another ought to be cheaper than the other.

It also means that one should focus on the development of a family of maglev system applications for use in urban mass transit, in which considerations of achieving the high speeds possible in inter-city service would not be primary, but ways to employ the new passenger-moving technology to increase the capacity in terms of passengers carried, over the shorter distances associated with intra-urban service, would be. That way, the development of maglev will be key to rebuilding decayed cities and, more importantly, building new cities from the ground up, while providing useful employment to, primarily, the urban unemployed.

The bar charts highlight some of the features. **Figure 4** takes the parameter from which the Chicago Fed's dollar cost assumptions were derived, but uses more recent estimates than those employed by the bank, to show an estimated maximum and a minimum dollar cost for the construction of 1 kilometer of a single lane of road or freeway, different types of single-tracked rail systems, and the maglev systems.

FIGURE 4
Investment cost
(millions $ per kilometer)

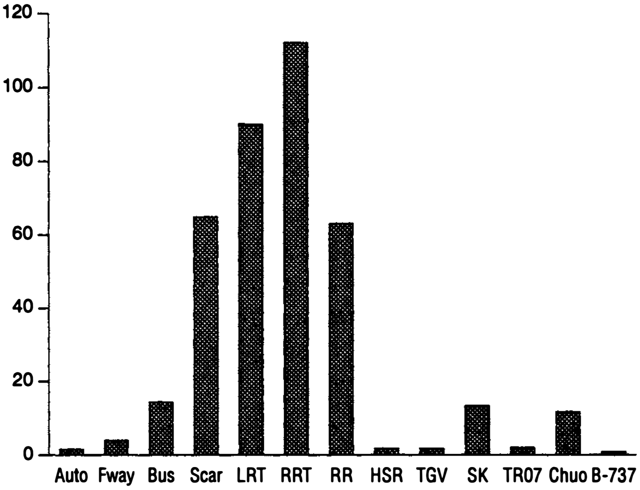


Sources: See Table 1.

The higher cost ranges for rapid and regional rail networks reflect the greater amount of construction work that has to be done in such grade-separated systems, that is, the tunneling and cover and fill embankment work. Freeways are similar, requiring access lanes, interchanges, and lots of bridge work. The parameters for High Speed Rail, TGV and Shinkansen, and the two maglev systems do indeed reflect what the Chicago Fed had to say. The second are twice as expensive as the first, and the third twice as expensive as the second, though all are cheaper than all the mass transit systems, except for street cars and buses. The maglev systems are about 20% more costly than freeways are to build, but the Higher Speed TGV and Shinkansen rail variants are much cheaper, about 60% of the cost. (Bus estimates, in this case, are different, because they do not include highway construction costs, but only lane divisions, stops and shelters, and so forth. Bus services are like airlines. Except for equipment purchases they do not have to fund capital improvements. They only pay operating costs, with the obvious exception of costs of equipment. We shall return to this matter.)

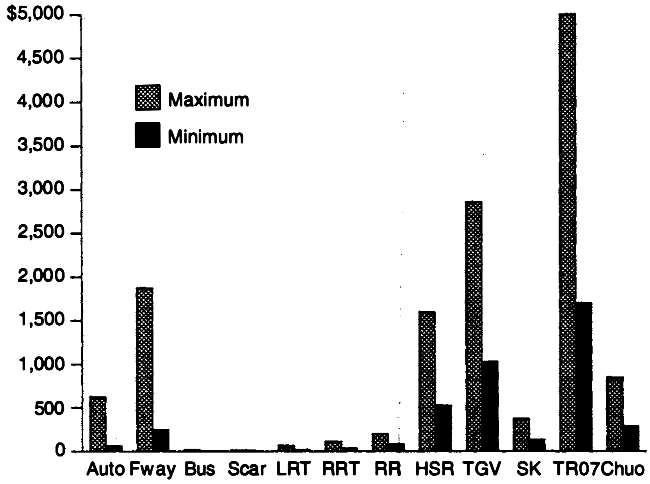
Figure 5 shows the line capacity of each of the identified systems. With the exception of the bus, the mass transit modes each can move more than 60,000 people over one kilometer of track, compared to 1,600 for automobiles. If the TR07 were organized as Budd proposed, with 500-800 passengers, the line capacity in that case would increase to 5-8,000 passengers, comparable to that claimed for the Chuo Linear Express with its 980 seats. Each would then potentially double the line capacity of a freeway lane.

FIGURE 5
Line capacity
(thousands of passengers per hour)



Sources: See Table 1.

FIGURE 6
Investment cost per passenger capacity per hour



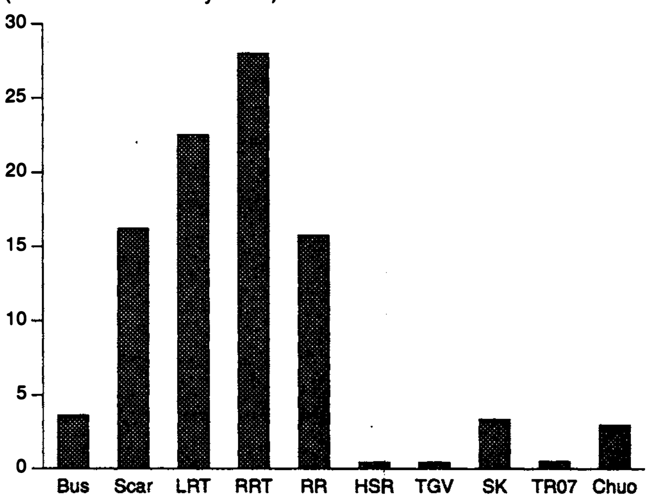
Sources: See Table 1.

The dollar cost per unit line capacity is shown in **Figure 6.** The mass transit modes, with the exception of buses, cost more per mile, and have the highest line capacity. They are, not surprisingly, the cheapest to build per unit of capacity. Regional rail at $198 per passenger is the most costly among them. Rapid rail, which can carry more than 100,000 passengers over each line of track, and costs about $25 million per kilometer to build, turns in at $111, and the street cars and light rail at $15 and $66, respectively. Use of these systems is determined by rush-hour peaking travel patterns. There are only about two hours in any day, morning and evening rush hours, when such capacities would be anywhere near utilized. But, urban freeway use is also subject to such peaking patterns, and those patterns have never been used as an argument against the construction of a system which costs about 10 times more than Regional Rail systems per unit of capacity, and 18 times more than Rapid Rail.

Figure 7 shows the number of freeway lane kilometers which would have to be built to equal the line capacity of each of the other modes. Things look different once it is realized that the capacity of one Rapid Transit Line is equivalent to that of 30 freeway lanes.

Line capacity differences translate thus into land requirements for different modes. The number of freeway lanes required could be multiplied by the lane width reported in Table 1, and compared to the track width or right of way requirement for each of the other modes.

FIGURE 7
Freeway lanes needed to obtain equivalent line capacity
(kilometers of freeway lanes)



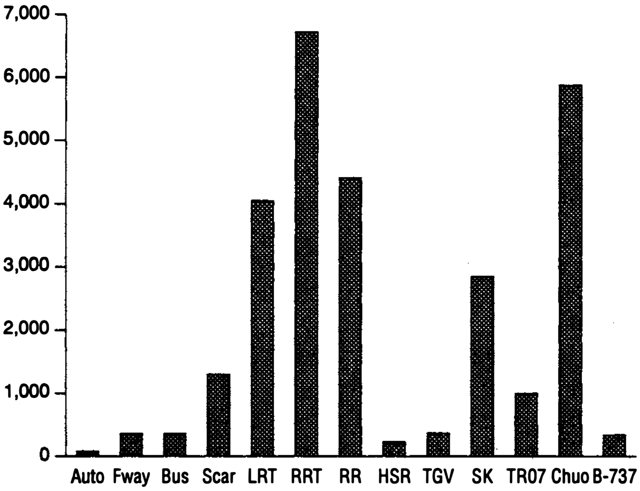
Sources: See Table 1.

Money considerations not decisive

These relationships begin to highlight the absurdity of the Chicago Federal Reserve's approach. By their method, urban freeways and streets would be the system of choice, relative to mass transit, on the grounds established as defining cheapness. This is one of the ways in which a system which is apparently the cheapest way to go, turns out to be among the most costly—in the cited case of Rapid Rail and freeways, by a factor of 30. Money grounds alone are not decisive; what can be done with the money is so much less.

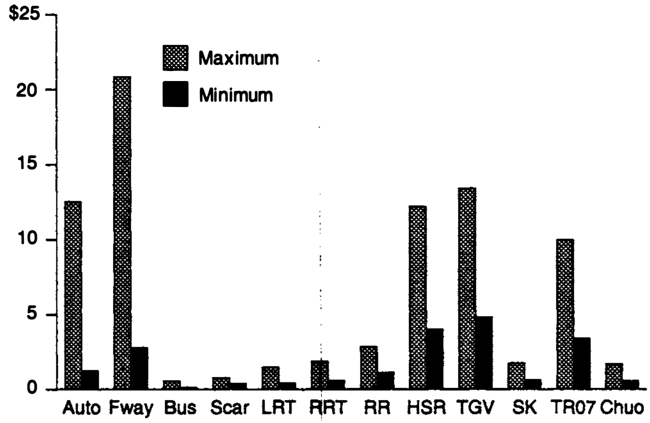
Note, further, in Figure 6, that, contrary to the Chicago Fed's conclusions, the Chuo Linear Express maglev is half

FIGURE 8
Productive capacity
(thousands of passenger-kilometers per hour²)



Sources: See Table 1.

FIGURE 9
Investment cost per unit of productive capacity
(thousands $)



Sources: See Table 1.

the dollar cost per unit line capacity of a freeway lane, one-third of the TGV, and about 60% of the High Speed Rail variant. It is cheaper than everything except the Shinkansen. And note that the 500 and 800 capacity versions of the TR07 would bring that system down to $2,000 and $1,250 per unit line capacity, the latter being cheaper than the TGV, comparable to the High Speed Rail variant, and competitive, using these parameters, with the cost of providing freeway auto service. These considerations reverse the Chicago Fed's apparentderivation of costs. They have the whole thing backwards.

Figures 8 and **9** compare the productive capacity of each of the identified systems, and the dollar cost, per unit of productive capacity. Now, speed, or distance traveled in an hour, is considered together with the number of passengers moved, as the expression passengers per hour times speed per hour, which reduces to passenger-kilometers per hour squared. Note again that the Chicago Fed's conclusions are reversed. The Chuo Linear Express, and the 800-seat version of the German maglev, thanks to the increase in speed, move up to the productive capacity range of the mass transit systems, which are moving many more passengers, but at far lower speeds. The Chuo Linear Express and the 800-capacity maglev are, respectively, nearly twice and 30% more productive than the Shinkansen, and from nearly 16 to three times more productive than the TGV with the 200-seat capacity TR07. The TGV, in its turn, is 1.6 times more productive than the Chicago Fed's preferred cheapest High Speed Rail variant.

In terms of its parameters, the Chicago Fed identifies as cheapest that which is most costly, in terms of system capability, and has the ranking of choices exactly backwards.

This is shown again in Figure 9, which compares the dollar cost per unit of productive capacity. While the 200-seat maglev variant is approximately 30% cheaper in performance terms than the TGV or so-called High Speed Rail, the 800-seat variant and the Chuo Linear Express system are about one-sixth the dollar cost per unit productive capacity of the TGV, and roughly the same in relation to the High Speed Rail system. Again, the Chicago Fed has the whole thing backwards.

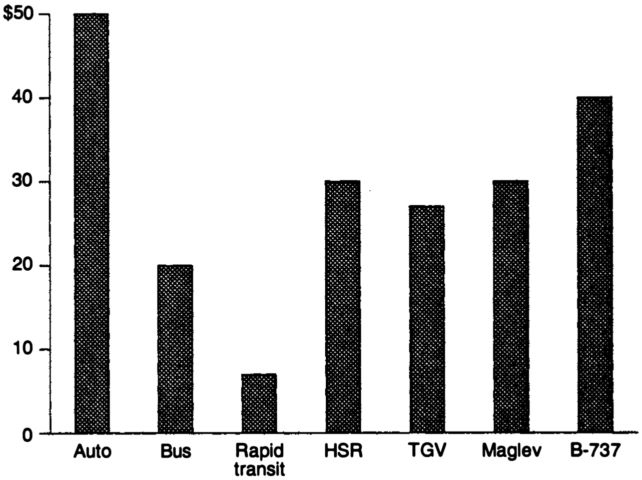
Since we are crazy enough to use freeways for inter-city travel in the way we do, it is worth pointing out that the difference between freeway costs per unit productive capacity, and the 800-seat maglev version and the Chuo is a factor of about 40. Some economic method, which could produce results like that and still be tolerated. One can still hear the Chicago Fed and its co-thinkers insisting that freeways are cheaper to build per lane-mile than is any kind of railway per track-mile. Again, note that the maglev systems are down in the range associated with the highly productive urban mass transit forms of transportation.

Paying for bad decisions

It's not an abstract matter. We ripped out the last of the street car lines in the 1950s and 1960s to make way for the freeways on the basis of precisely this type of thinking. Thereby, to create markets for the auto companies, and restrict people's choices of travel to autos and planes, we incurred travel costs some 40 times greater than those associated with the ones we were junking, at least where urban service is concerned.

The economic life-span of those decisions haunts us over the 30 years, and longer, the investment is expected to last. We're paying now, in the form of a quarter-trillion-dollar annual bill for highway congestion-related losses, and the economic losses associated with the health and insurance

FIGURE 10
Operating costs
(cost per 1,000 seat-kilometers)



Sources: U.S. Congress, Office of Technological Assessment, "New Ways: Tilt Rotor Aircraft and Magnetically Levitated Vehicles," October 1991; U.S. Department of Transportation, Federal Railroad Administration, "Assessment of the Potential for Magnetic Levitation Transportation Systems in the U.S.," June 1990; Vukan Vuchic, *Urban Public Transportation, Systems and Technology*, Prentice-Hall, 1981.

costs of auto travel. Some 10% or more of the $600 billion-plus annual expenditures on health care are related to automobile accidents. By comparison, there has never been a fatality associated with the operation of the Shinkansen in all the years of its existence since 1964.

The cost of building road, track, or guideway facilities is only part of what is involved. There are also the costs of operating the service to be considered. **Figure 10** compares operating costs, in dollars per 1,000 seat-kilometers, for a selection of the identified systems. Rapid Transit will here have to typify all of the mass transit forms otherwise identified. It can be assumed that its operating costs are lower than for street cars and light rail systems, but higher than the regional rail service arrangements.

Operating costs should include the labor required to run each of the systems, the fuel or power bill, maintenance of the operating equipment, and also of the road, track, or guideway, and subsume the expenses associated with ticket sales, administration and management, and insurance.

The per passenger-kilometer cost of operating an automobile reflects prevalent levels in the U.S., including, obviously, U.S. gas prices. Bus and Rapid Transit system operating costs are an average of various transit systems within the United States. The estimates for the other modes are taken from studies produced by the U.S. Department of Transportation (DOT) and the Office of Technology Assessment (OTA).

The 3¢ per passenger-kilometer figure for High Speed Rail is the OTA's version of operating costs on Amtrak's Metroliner. It can be compared with what the DOT calls Amtrak's "non-avoidable" operating costs, which amount to 16¢ per passenger-kilometer.

The maglev estimates are again based on the Budd Corp.'s studies which, in the case of the proposed Los Angeles-Las Vegas route, were cross-checked by the Canadian Institute for Guided Ground Transport. The relevant features are: Maglev manning requirements are about one-third of those used in Metroliner service—one operator and one on-board worker for each 100-person vehicle, against the operator, conductor, trainmen, and on-board service employees of the Metroliner. The ratio is comparable to TGV and Shinkansen manning levels, too. Vehicle maintenance will be about one-sixth of that required for the Metroliner—the benefit of not having moving parts to worry about. Maintenance workers, however, will require very different, higher skill levels.

From the internal economics of the transport systems, revenues earned from operating the system are supposed to more than cover operating costs, such that the balance is available for, among other purposes, payments to be made on the capital account of financing system construction. In this approach, like that, for example, employed by the Chicago Federal Reserve, the money capital requirement of financing line construction, adjusted for inflation over the life expectancy of the project, say 30 years, and subject to interest, then provides a basis for estimating what revenues should be, in order to cover so-called capital costs and operating costs. What is really being projected in the approach typified by the Chicago Federal Reserve is an estimate of the debt service and amortization burden that can be supported from the net revenue flow after operating costs have been deducted. Using per line mile or kilometer money figures (prices) as the Chicago Federal Reserve and others do, is a simple and effective way of increasing that ratio in favor of those who supposedly finance the project.

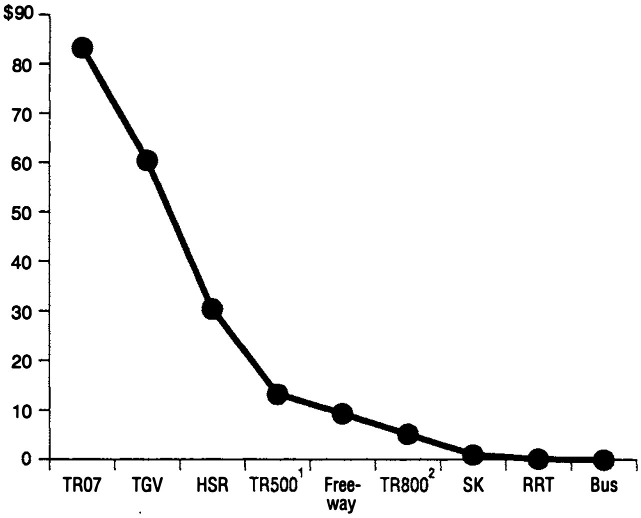
Short-term profitability

Given an estimated price-tag for a system, the question always comes up, "How will it be paid for, and who will pay for it?" The answer to the first part usually takes one of the following forms: tax exempt bonds, taxable bonds, or some form of equity participation. The answer to the second is the usual suspect in such circumstances, all of us.

Estimated construction costs are then discounted back to the mid-point of construction work from an estimated, say 30-year, life of the investment to allow for the depreciation of money over the whole period. An interest rate is calculated on the basis of the assumed inflation discount and what is called a "reasonable" rate of return. The Department of Transportation, in its 1990 study on maglev, assumes a 4% annual discount for inflation, such that the first year's dollar is worth 96¢ in year 2, and less than 1¢ in year 30, plus an 8.5% "reasonable" tax-free rate of return, or 12.5% per annum, for its maglev estimates. The "taxable" rate would yield an annual interest charge exceeding 15% in total. The

FIGURE 11

Cost per unit line capacity over operating costs at capacity

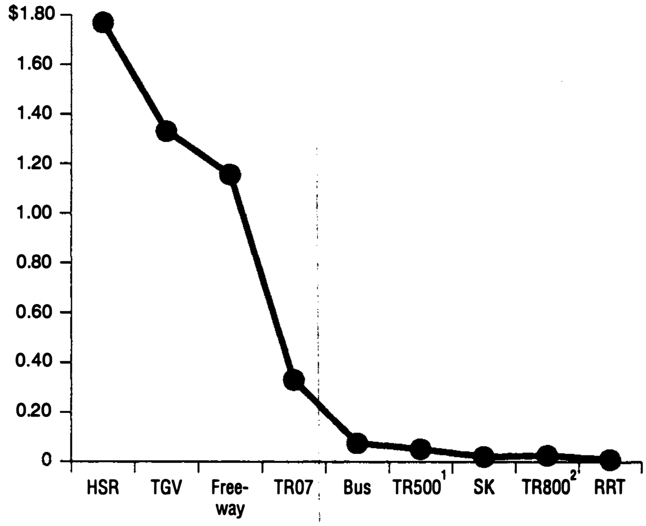


1. The 500-passenger version of TR07 as proposed by the Budd Corporation.
2. The 800-passenger version of TR07.

Sources: See Table 1.

FIGURE 12

Cost per unit of productive capacity over operating costs



1. The 500-passenger version of TR07 as proposed by the Budd Corporation.
2. The 800-passenger version of TR07.

Sources: See Table 1.

Chicago Fed employed a so-called "real interest rate" of 6% in its calculations, but those were in the days of double-digit inflation, and translate into a financing charge compounding away at 16% per annum.

It is not difficult to figure out what such an approach does to the initial estimate of investment cost. After about seven years, in the tax-free version, and five in the taxable version, interest and discount charges will more than amount to the total of the initial borrowing. But the compounding will continue inexorably. In this approach, an economically useful project is reduced to a special kind of money-making machine, as the initial investment in capital improvements is transformed as rapidly as possible into cash which is sucked out of achieved, or anticipated, revenue streams. Cost estimates, like those undertaken by the Chicago Federal Reserve, then become simply a means for assessing what the flow of cash to be extracted from a project can be estimated to be in relation to an initial investment.

Given the interest-plus-inflation formula, the so-called threshold of financial profitability will be much higher for those systems which appear to have a higher initial investment cost, especially if costs are not calculated on the basis of line and productive capacities. Therefore, such projects, like maglev, will appear to be unviable because they generate less for bond-holders than apparently cheaper projects which have a lower threshold of profitability. And, thus, we blunder from stupidity to stupidity. Running transport systems which are up to 40 times more costly in economic terms than they have to be, and paying at least four times too much, in money terms, for them, after the effects of compounding are taken into account. J.P. Morgan's trust company is still collecting on mortgages against railroad track taken out in the nineteenth century.

Figure 11 illustrates how this works at the level of estimating the required revenue stream, but not taking things further to include the compounding of interest and depreciation of money. The graph plots the ratio between the dollar cost per unit of line capacity, and the operating costs sustained in running at that capacity. The result is the factor by which operating costs would ostensibly have to be increased to support capital construction. Since line capacity is based on frequency, it is comparable to Figure 2, in which capital costs are plotted as a function of frequency. And, not suprisingly, it produces a result comparable to that employed by the Chicago Federal Reserve to argue against maglev systems. For every dollar incurred in operating the 200-seat TR07, more than $80 would have to be generated in revenue before compounding goes into effect. Obviously, this is not a viable proposition. From this, nothing is really viable until we get to freeways at about 10 times the operating costs.

But that's what we've been doing.

It is therefore no more a useful tool for assessing costs than the one employed by the Chicago Fed. And not simply because of the result. We saw that productive capacity is a better measure of capacity than line capacity. **Figure 12** plots the ratio between the dollar cost of constructing each unit of productive capacity, and the dollar cost of operating each respective system at its productive capacity. As before, we are including the speed of the system as well as the number of passengers carried per hour.

Note first what happens to the left-hand scale. No longer counting in tens of dollars as in Figure 11, we are now counting in dollars and cents. Note also, how the ordering is reversed. Now High Speed Rail is more costly than the TGV, the TGV is slightly more costly than freeways, and the TR07 is cheaper than both, by more than a factor of three. The graph would bear out the earlier assertion that maglev will reduce the cost structure of inter-city transportation to the level now associated with urban mass transit. The sum of operating costs plus capital expenditures, at 6.75¢ per passenger-kilometer, would translate into slightly more than $29 for the 440-kilometer trip between New York City and Washington, D.C. A reasonable, maximum 10% profit would be turned on a trip that cost $31.90.

This calculation assumes that the service would operate at capacity, in the way productive capacity was calculated above. That obviously won't happen all the time, and couldn't, given traffic-peaking patterns which would apply in a service that could reduce travel time, city center to city center, to about an hour between Washington and New York. If we then assumed, as airlines do, that 65% of seats must to be sold to break even, we would be left with a one-way ticket price of around $50. The greater capacity, 500 and 800 seat versions of the TR07 could be expected to reduce ticket prices further, as indicated. But, there would be more capacity to fill.

If compounding of money depreciation and interest were permitted, the identified fare structure would still be competitive with existing rail and airfare structures. But, why tolerate that?

Financing with credit, not debt

There is no reason why anyone should have to go into debt to build such projects. What is needed is not debt, but credit to get the construction process of line, or guideway, and operating equipment going. This way is to opt for the "third" financing route, which neither the Chicago Federal Reserve nor the Department of Transportation really considered: equity financing. It is not taken seriously because the equity purchaser assumes all of the risks of ownership, such as making good everything that goes wrong, and receives none of the benefits which bond-holders do. Thus, in bankruptcy, the worst case of everything going wrong, the bondholders are right there in line after employees and holders of accounts receivable, waiting for their pick of the assets. Equity holders aren't; they have to make good on the claims.

Figure 13 shows some of the lines that have been projected for maglev transportation in the United States. It is based on the Department of Transportation's cited 1990 study. **Table 2** lists the individual stretches by region, together with line length and construction cost at $10 million per kilometer of single guideway. The whole amounts to 10,000 kilometers of guideway for a total of just over $100 billion. Double-guideways, if used everywhere, would obviously double the price tag to $200 billion.

Divide the $100 billion price tag by 6.75¢ per passenger-kilometer. Some 1.5 trillion passenger-kilometers would generate the revenue to pay for the whole $100 billion of the single track version. That may sound like a lot, but it is less than the total volume of present yearly inter-city traffic by automobile. And if it is pro-rated over seven years, the 214 billion passenger-kilometers required would be significantly less than the total present yearly volume of inter-city air travel.

The first 10,000 kilometers of a national network could be constructed, with double guideways, for the same amount we are now incurring by way of the combination of traffic congestion and costs paid out by health and insurance systems for auto accidents. Suppose this Phase 1 of national network construction proceeds over 5-7 years. It amounts to $40 billion a year over five years, or $28.75 billion per year over seven years. Costs of guideway construction are estimated to be 80% of the total costs of guideway construction and equipment purchases for the system. An additional $20-40 billion will therefore be needed for the equipment. Phase 2 of such a project can be envisaged by filling in the gaps between the identified nodes.

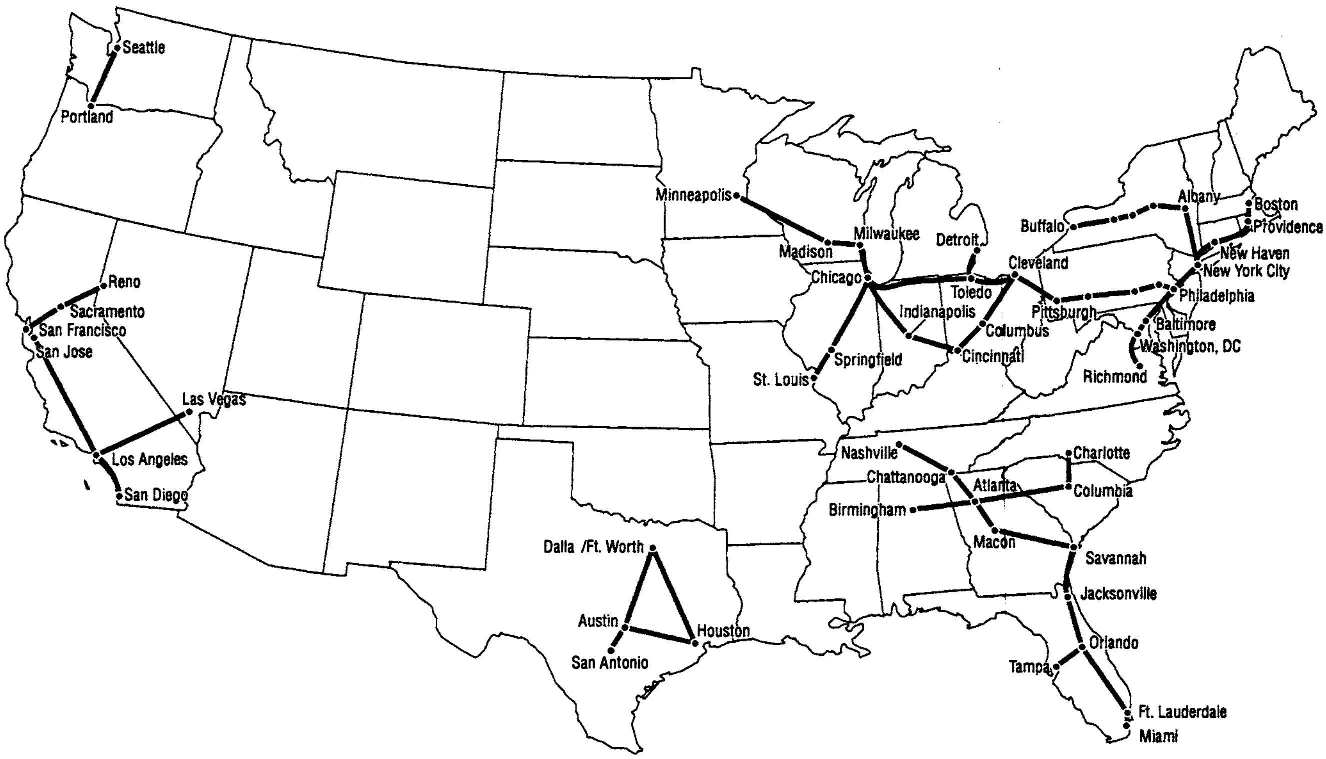
The approach adopted to prove the viability of maglev systems assumes that such projects should be internally viable, so to speak. That is to say, that they should be able to stand on their own feet without regard to any external parameter. This we noted before was not the case with bus or air traffic. Neither carry costs of facility construction. Such a condition is helpful in evaluating such projects, but it is not a necessary one, nor is it sufficient. Nor is it therefore necessary to assume that users alone bear the cost of constructing such projects. We certainly do not impose such standards on highway or airport users, though we claim that "user fees," gas taxes, registration charges, and other taxes help cover the costs, which they don't.

There are circumstances in which external conditions or benefits of a project would alone be justification. Do we expect the space program to be self-financing? Of course we do not. It would be insane to expect NASA to develop a revenue generating capability which could support the investment necessary to sustain scientific work in space.

Despite that, we are running the shuttle program as a "commercial program," charging corporations which want the service to lift their payloads into space. And we are thereby diminishing NASA's scientific capability by misdirecting its resources. In the 1960s, during the Apollo Program, which was not a revenue generating program (though one could work out how much Sen. John Glenn [D-Ohio] might have had to pay for the privilege of his trip), NASA returned $14 to the economy for every $1 sunk into the effort.

It was not so different during the period of railroad construction in the nineteenth century. Contrary to those who insist that a "need" for a project, in the form of a potential revenue base, be proven to exist before the project can be undertaken, once settlement of the country reached the prairies, railroad construc-

FIGURE 13
Examples of maglev networks



Source: U.S. Department of Transportation, Federal Railroad Administration, "Assessment of the Potential for Magnetic Levitation Transportation Systems in the U.S.," June 1990.

tion preceded settlement. That which was supposed to provide "needs" and therefore a revenue base, itself created a need for settlement which had not existed before. The post-Civil War rule-of-thumb estimate was that the mere construction of a railroad line through, or into, an area, would return $4 for every $1 spent in the construction process.

A project can be a loser internally, but still produce benefits for the society and economy as a whole. The benefits will more than pay for the project from an overall economic standpoint.

This points to the limitations of what we have reviewed so far. In the 1950s, this type of approach would have been standard for a production engineering approach to cost accounting, even in U.S. manufacturing corporations. That was in the days before the finance officers and the accountants took over. The approach was also employed by electric utilities and, to some extent, in the transportation sector. Nowadays, only vestiges remain—in the United States, primarily among computer manufacturers who have improved the capacity of their product and lowered its price according to the old-style rule of thumb. It is also part of what is known in Japan as the method of "quality control" in manufacturing, adopted from the United States after World War II.

The governing idea was not what you produce and how you market it, but how to improve the production process to make a better product more cheaply. This is how the Japanese were able to improve the quality of their automobiles, while cheapening prices at a rate sufficient to stay ahead of the collapse of living standards in their biggest export market, the United States. Such might appear to be a viable policy over the short to mid-term. But over a longer time frame, it has been doomed to failure.

The production engineer's approach employed here favors technological innovation to improve capacity, or product quality, while simultaneously reducing costs. The finance officer's approach, typified by the Federal Reserve study, will invariably, except under the most extraordinary conditions, rule out the introduction of new technological processes on grounds of cost, lack of proven revenue base, or market, and will cook up the most contrived, swindling rationalizations, such as those employed by the Chicago Federal Reserve, to defend more expensive existing processes from cheaper, newer ones. In each case, it will be found that the introduction of the new technology would wipe out the revenue flows attached to the bonds which were issued to finance the more costly old one. And for that reason alone the finance officer could properly claim the new technology

TABLE 2
Rail distances and investment costs

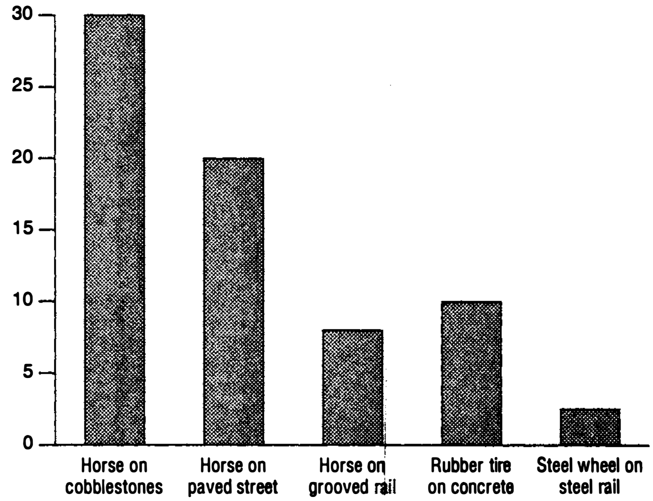
City pair	Distance (kilometers)	Cost (billions $)
Northeast:		
Boston – Washington, D.C.	721.6	$ 7.216
Montreal – New York City	528	5.28
Buffalo – New York City	468.8	4.688
Philadelphia – Pittsburgh	560	5.6
Washington, D.C. – Richmond	187.2	1.872
Total Northeast	2,465.6	24.656
Southeast:		
Nashville – Atlanta	460.8	4.608
Birmingham – Atlanta	267.2	2.672
Columbia – Atlanta	406.4	4.064
Atlanta – Jacksonville	560	5.6
Jacksonville – Miami	585.6	5.856
Total Southeast	2,280	22.8
Midwest:		
Chicago – Detroit	435.2	4.352
Chicago – St. Louis	454.4	4.544
Chicago – Milwaukee	136	1.36
Chicago – St. Paul	633.6	6.336
Chicago – Cincinnati	449.6	4.496
Detroit – Cleveland	262.4	2.624
Cleveland – Pittsburgh	209.6	2.096
Cincinnati – Cleveland	416	4.16
Cleveland – Buffalo	294.4	2.944
Total Midwest	3,155.2	31.552
Southwest:		
Dallas – Houston	422.4	4.224
Houston – San Antonio	336	3.36
San Antonio – Dallas	433.6	4.336
San Antonio – Austin	105.6	1.056
Total Southwest	1,297.6	12.976
West:		
San Diego – San Francisco	956.8	9.568
San Francisco – Los Angeles	752	7.52
Los Angeles – San Diego	204.8	2.048
Los Angeles – Las Vegas	353.6	3.536
Seattle – Portland	291.2	2.912
Total West	1,601.6	16.016
Total U.S.	**10,800**	**108**

Source: *EIR.*

to be more costly. But, the question is, more costly to whom? All bond-holders, a class of bond-holders, or the rest of us?

The question of technological advance, which divides the two approaches, is the one which also permits an assessment of the effects of the introduction of any new system on the economy as a whole, and whether a project, which would not be viable on its own, would still be feasible from the broader standpoint of the whole economy. It also poses the question of what it is which distinguishes mankind absolutely from the lower beasts. Because, of all creation known to us, mankind is unique in employing the power of technology to transform the conditions of his own existence. The creative power of the individual human mind advances the science which permits the development of the power of technology, whose application enables more human beings to be supported, in better conditions, on less land. To the extent that a technological innovation contributes to that process of continuing mankind's advance, despite the "it's too costly" protestations of the Chicago Federal Reserve and its anti-human friends, it therefore will be and should be usefully adopted, whether or not it also happens to be internally viable in the terms discussed above.

FIGURE 14
Friction and power
(kilograms of tractive power required to move one ton)



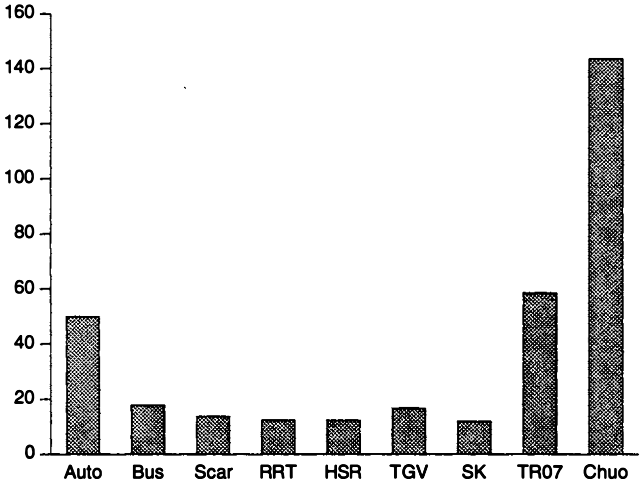
Source: John P. McKay, *Tramways and Trolleys,* Princeton University Press, 1976.

The maglev system advances the level of technology, and will contribute to improving the lot of all mankind.

Technological advance can be represented by the increase in the energy flux density of the process applied. Take some butter, try to cut it with a piece of metal. The result will be a mess. Now, take a metal edge, like a knife. The same pressure applied to a different metal instrument accomplishes a vastly different, more useful result.

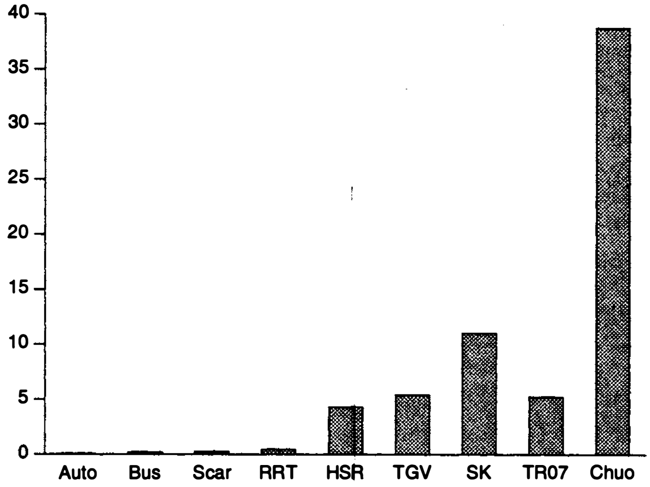
In ground transportation systems, this process is reflected in the tractive power needed to move a load over different kinds of surface against the associated friction. **Figure 14** exemplifies how the tractive power to move a load, which can be thought of as a succession of better kinds of knife-edge, has decreased, as the technology associated with moving goods and people has improved from the use of animal power which dominated in and before the nineteenth century. The reported 2.5 kilograms to move one ton, for steel-wheels rolling on steel rails, is a conservative estimate. This can be as low as 1 kilogram per ton, 10 times better than rubber on highway.

FIGURE 15
Power-to-weight ratio of transport unit
(kilowatts per ton)



Sources: See Table 3.

FIGURE 16
Power of transport unit
(thousands of kilowatts)



Sources: See Table 3.

There is no such constraint on the maglev surface transport systems because, suspended as they are for magnetic quasi-flight, there is no friction to be countered. In the German system, 4 of the 60 kwh required for each passenger-kilometer are required to lift the vehicle, the rest to move it forward.

Beyond the power that has to be applied to move a load against friction, there is also the method by which the tractive power is applied. With rail systems, this can be measured in the ratio between the power output of the source of supply, and the power applied at the drawbar where the locomotive unit is connected to the load.

By the time of the last generation of steam engines, roughly 1950, after nearly 130 years of work, this ratio had reached 8% for steam traction. In diesel locomotives such as those used in the United States, where the efficiency of the engine can be assumed to be 30-40%, some 22% of the power is applied at the drawbar. In electric traction, assuming a 95.2% efficiency between generating station and the substation which transfers power to the train's motor, the efficiency between the substation and the drawbar is 72% for a single-phase alternating current (AC) unit, and 69% for a direct current (DC) unit. If the efficiency of the primary source of supply is considered, then the power applied at the drawbar will be in the range of 25%.

All three of these systems work against the same constraint of steel-wheel against steel rail. Diesel and electric systems do so roughly three times more efficiently than steam did. Since the maglev systems do not have to sustain efficiency losses between on-board supply (there is no on-board power unit) and drawbar, the efficiency of power conversion would be that between substation and unit (95.2%), and thus, as with electric traction, allowing for generation losses, over 30%.

In this system, as also with electric traction, improvements would not only depend on advancing the transport technology itself—for example, advances associated with superconducting materials—but also on economy achieved in the generation of electric power. Present combined-cycle gas turbines, which operate with greater than 50% efficiency in power generation, would improve the efficiency of maglev systems to better than 47%, and would, of course, do the same for electric traction.

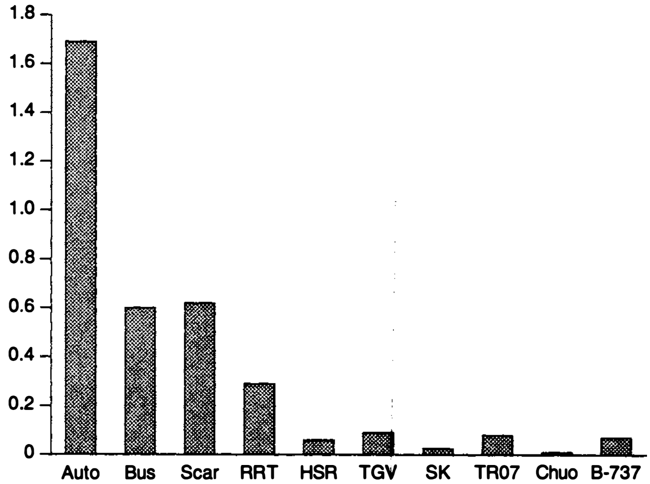
This points to the standing post-World War I idiocy in U.S. transportation practice. In 1916, the decision was made not to electrify the U.S. rail system, and even to rip out chunks that had been electrified. The argument employed was the one we are familiar with, cost. Except where "density of service" merits it, electrification was said to be too expensive. And thus, the United States went back to steam, and then sideways, as it were, to diesel. Why sideways? Because diesel traction is a relative dead-end. Electric traction systems have advanced along a line dictated by the problem of improving and increasing the power delivered to the traction unit. There is no such line of advance available to diesel traction systems, which are limited to an upper speed of 125 miles per hour (200 kilometers per hour), and need an electric transmission to develop the torque necessary for starting and operating at low speed. Requiring less maintenance, electric traction can deliver twice as much continuous power to the drawbar as diesel locomotives. **Figures 15** and **16,** representing kilowatts power-per-transport unit and power-to-weight ratio for the different systems considered, show the results of this process in terms of increased power made available, and shows, in the latter

TABLE 3
Energy and power parameters

Mode	Power (kw)	Gross weight (tons)	Power/ weight (kw/ton)	Vehicle- km/kwh	Passenger- km/kwh
Auto	75	1.5	50.00	1.69	3.39
Bus	213	12	17.75	0.6	24
Scar	260	19	13.68	0.62	62
RRT	470	38	12.37	0.29	40.6
HSR	4,325	350	12.36	0.06	21
TGV	5,450	386	16.71	0.09	31.5
SK	11,040	927	11.91	0.025	33.5
TR07	5,280	90	58.67	0.08	16.6
Chuo	38,800	270	143.70	0.011	11.1
B-737				0.07	8.9

Sources: U.S. Department of Transportation, Federal Railroad Administration, "Assessment of the Potential for Magnetic Levitation Transportation Systems in the U.S.," June 1990; U.S. Congress, Office of Technology Assessment, "U.S. Passenger Rail Technologies," 1983; Vukan Vuchic, *Urban Public Transportation, Systems and Technology,* Prentice-Hall, 1981.

FIGURE 17
Vehicle-kilometers per kilowatt-hour



Sources: See Table 3.

figure, a further advantage of the maglev systems in the form of a drastic improvement in the power-to-weight ratio. **Table 3** summarizes the information plotted.

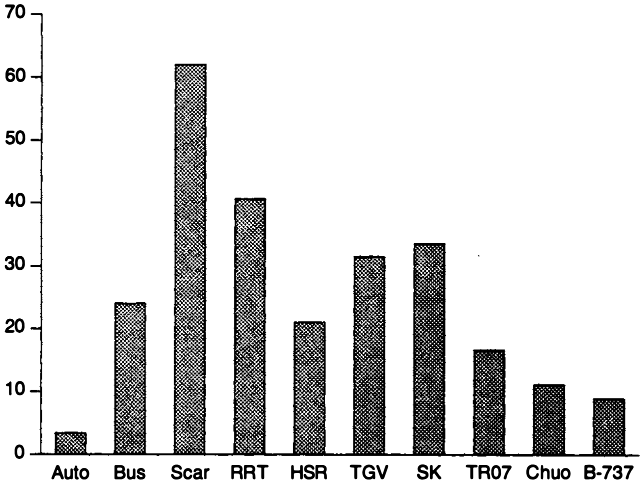
The improvement represented by the maglev system jump in the power-to-weight ratio is the result of the employment of technology based on new physical principles which no longer require the power unit to be carried on-board the vehicle. TGV and Shinkansen increase the power available per unit, but do not substantially change the power-to-weight ratio relative to, for example, High Speed Rail. TGVs and Shinkansens were made possible by advances in transmission of power from generating unit to substations, and in methods of controlling power on board the locomotive units. This is a by-product of electric traction systems moving from a DC supply working with multiples of a 750-volt current up to 6,000-volt current, through single-phase AC systems, employing transformers with on-board motor operating at 10-15,000 volts, and at lower than normal industrial frequencies, 16⅔ hertz compared to 50 hertz. This advance reduced the required cross-section of the contact wire from 400 millimeters for a 1,500-volt system to 150 millimeters for a 10-15,000-volt system, and therefore reduced the weight of the power delivery system, and also reduced the number of power substations required, from one every 15 kilometers of track, to one every 40-60 kilometers of track. The TGV and the Shinkansen employ monophase-triphase group systems employing static current rectifiers and thyristors and currents of 25,000 volts. If a 1,500-volt current is assumed to be standard for DC supply, this is nearly a 17-fold increase in voltage delivered over the period since the end of World War II. This is what the electrified French system was able to achieve.

The United States shut itself out from this process to such an extent that foreign expertise, in the form of the ASEA Brown Boveri company, had to be called in to help manufacture the locomotive units for the 87-mph Amtrak Northeast corridor Metroliner service. Now the idiots in the U.S. railways are trying to figure out how to convert the DC transmissions on their diesel engines to AC power so that they can get another 30 years of life out of their poor old diesel locomotives.

The summary in Table 3 of the energy and power characteristics of the transit systems we have considered above, also includes data for the power consumption per vehicle-kilometer and per passenger-kilometer (see **Figures 17** and **18**). The increased power of High Speed Rail, TGV, and Shinkansen, relative to the mass transit forms which would employ a 600-800-volt DC power system, is shown as a decline in the number of vehicle-kilometers accomplished for each kilowatt-hour of power consumed. An 800-seat system based on the German technology will probably require about 20 megawatts (MW) of power for a 400-500-kilometer trip. The Japanese system is approaching a power requirement of 40 MW for such a trip. The principal constraint that will be encountered in developing the system for service will be that of making available sufficient power. To support frequencies of 10 trains an hour in each direction over 400 or so kilometers will require between 400 MW of power for the German system and 800 MW for the Japanese. That's enough electrical power to support 25-50,000 U.S. households for a year.

However, it can readily be argued that the TGV and Shinkansen are to maglev systems as the diesel traction loco-

FIGURE 18
Passenger-kilometers per kilowatt-hour



Sources: See Table 3.

TABLE 4
Transit density per household in selected countries in 1970
(thousands of passenger-kilometers per household)

Mode	U.S.	West Germany	India	Japan	China
Rail	0.284	1.728	1.102	5.697	0.408
Road	26.687	18.326	1.578	10.575	0.136
Water	n.a.	n.a.	n.a.	0.179	0.040
Air	3.013	0.300	n.a.	0.350	0.001
All modes	29.968	20.361	2.679	16.793	0.583

Sources: International Road Federation, Geneva, *1972 Yearbook*; World Bank, "China: The Transport Sector," 1985.

TABLE 5
Network density in selected countries, circa 1970
(kilometers per km²)

	U.S.	West Germany	India	Japan	China
Roads/total area	0.631	1.773	0.363	2.795	0.098
Rail/total area	0.057	0.129	0.019	0.066	0.007
Roads/built area	6.925	10.627	1.203	13.935	0.353
Rail/built area	n.a.	1.590	n.a.	1.152	n.a.
Rail routes/ built area	0.026	0.115	n.a.	0.602	n.a.
Streetcar routes/ built area	0.007	0.201	n.a.	0.070	n.a.

Sources: International Road Federation, Geneva, *1972 Yearbook*; statistical yearbooks of United States, Federal Republic of Germany, India, Japan, and China; *Jane's Mass Transit*.

motive is to the electric one. Just as a diesel-powered unit could not function without its electric transmission system, so the TGV and Shinkansen would not be able to function without the power-control systems which are part of the maglev requirement.

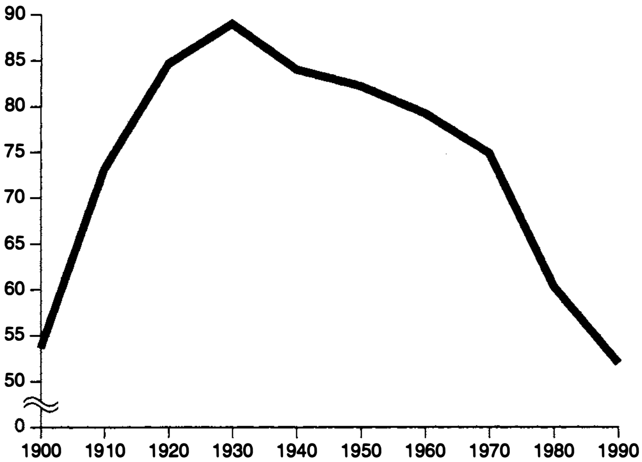
The conclusion ought to be drawn that this new propulsion method for ground transportation should become the technology of choice as rapidly as possible. Why waste money and labor perpetuating systems of transportation which are rendered obsolescent in ways more profound than was the horse by the steam engine, or the steam engine by electric traction? And which will have correspondingly earth-shaking benefits outside the field of transportation as such.

Tables 4 and **5** provide another way to think about the impact of such a system. Table 4 reports passenger-kilometers traveled per household, by mode, for the United States, West Germany, India, Japan, and China in 1970. There are two features to note. One is the dominance of the automobile in the United States, Germany, and Japan. The second is the absolute gap, a factor between 7 and 50, between the United States, Germany, and Japan on the one side, and India and China on the other. Table 5 shows the density of road and railroad grids for total, and urban land areas of the same countries at around the same year.

What is one to propose to such countries as India and China, which together comprise more than 20% of the world's population? That they should repeat all the blunders which we have made over the past approximate 100 years? That they should put scarce manpower and other resources into highway construction, territory wide, and in their cities? Or, that they should leap-frog the mess that we have made, and commit to a future technology which, while being relatively cheap, also has the potential to help transform everything?

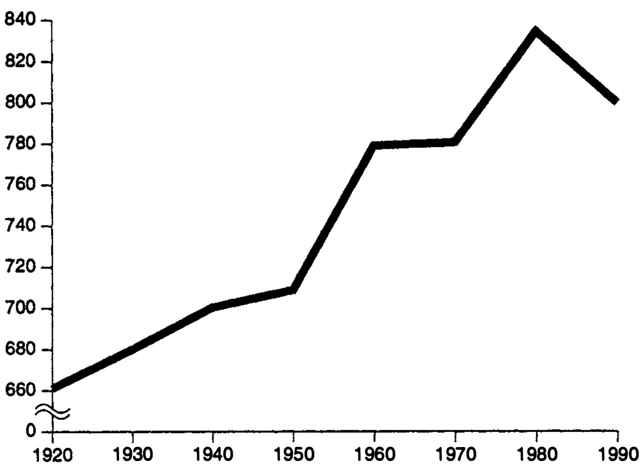
As for the mess that we have made, **Figures 19, 20, 21,** and **22** show how the same network density parameters have developed in the United States over the course of most of this century to date. These charts reflect the process by which the automobile and the highway became the transportation mode of choice. For every kilometer of railroad lost, 5 kilometers of highway have been gained. That's an absolute loss of productive capacity according to the relationships discussed above. The 5 kilometers of highway represent about one-quarter of the capacity lost in dismantling the 1 kilometer of railroad. Figures 21 and 22 reflect the same process at work in the cities. Of course, the absolute length of city streets has

FIGURE 19
Railroad density in the United States, 1900-90
(kilometers per 1,000 km² of land area)



Sources: U.S. Department of Commerce, Census Bureau, *Historical Statistics of the United States,* 1976; *ibid., Statistical Abstract of the United States.*

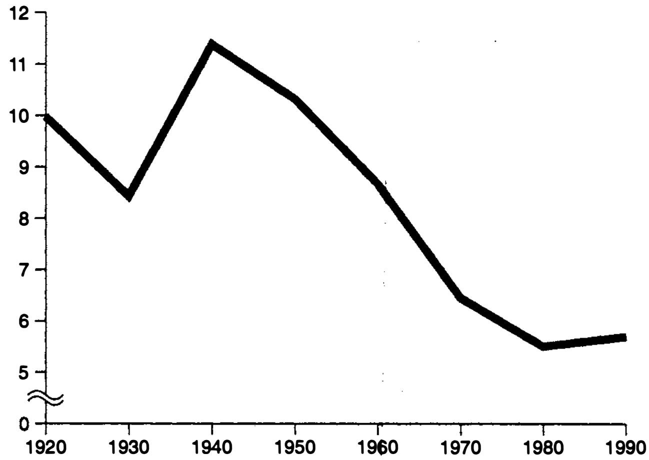
FIGURE 20
Road density in the United States, 1920-90
(kilometers per 1,000 km² of land area)



Sources: U.S. Department of Commerce, Census Bureau, *Historical Statistics of the United States,* 1976; *ibid., Statistical Abstract of the United States.*

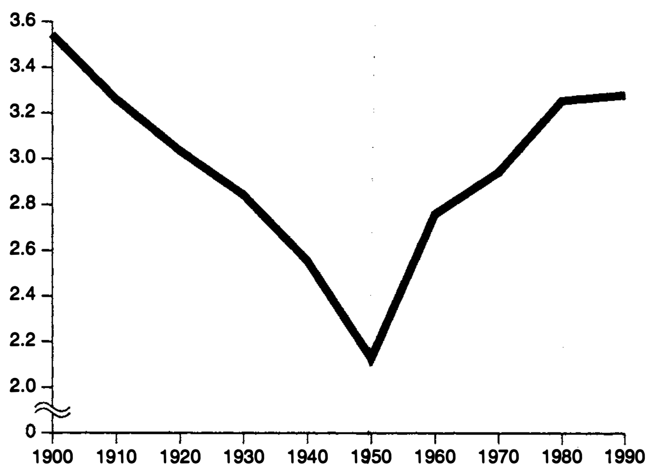
grown, but not as fast as urban area as a whole, under the influence of the automobile on suburbanization. And, thus, the number of households per urban area has declined, as the centralizing, and organizing focus of urban life was destroyed in favor of the suburbs. The burnt-out shells of the inner cities are the result.

FIGURE 21
Urban street density in the United States, 1920-90
(kilometers per km² of urban area)



Sources: U.S. Department of Commerce, Census Bureau, *Historical Statistics of the United States,* 1976; *ibid., Statistical Abstract of the United States;* Mario Clauson, *Land for the Future,* Johns Hopkins University Press, for Resources for the Future, 1960.

FIGURE 22
Built-up area per 1,000 urban households, 1900-90
(km²)



Sources: See Figure 21.

Rebuilding the transport grid will be a key part of rebuilding the cities. Maglev is the best way to do it.